

We Claim:

1. A magnetic sensor, comprising:

a. a giant-magnetoresistive sensing layer comprising a ferromagnetic free layer; and

b. a hard bias layer positioned and configured to maintain the free layer in a single-domain state,

wherein the hard bias layer has a coercivity of at least 2,000 Oe.

2. The sensor of claim 1, wherein the hard bias layer has a coercivity of at least 2,300 Oe.

3. The sensor of claim 1, wherein the hard bias layer has a thickness of not more than 60 nm.

4. The sensor of claim 1, wherein the hard bias layer comprises:

a. a seed layer comprising an alloy between two elements chosen from the group consisting essentially of W, Mo, Cr, V, Nb, Ta, Ti, Hf and Zr, wherein the two elements have different crystal structures; and

b. a permanent magnetic layer deposited on the seed layer, wherein the permanent magnetic layer comprises an alloy comprising Co and Pt.

5. The sensor of claim 4, wherein the seed layer comprises TiW with 1 to 15 atomic percent W, and wherein the permanent magnetic layer comprises CoPt.

6. The sensor of claim 4 wherein the seed layer comprises TiW with 1 to 15 atomic percent W, and wherein the permanent magnetic layer comprise CoPt_x, wherein *x* is an element chosen from the group consisting essentially of B, Cr, Ta, C, Zr, Rh and Re.

7. The sensor of claim 5, wherein the hard bias layer has a coercivity of at least

2,300 Oe.

8. The sensor of claim 5, wherein the hard bias layer has a coercivity of at least 2,500 Oe.

5

9. The sensor of claim 6, wherein the hard bias layer has a coercivity of at least 2,300 Oe.

10. The sensor of claim 6, wherein the hard bias layer has a coercivity of at least 2,500 Oe.

10

11. The sensor of claim 1, wherein the hard bias layer comprises:

- a. a seed layer comprising an alloy between two elements chosen from the group consisting essentially of W, Mo, Cr, V, Nb, Ta, Ti, Hf and Zr, wherein the two elements have different crystal structures; and
- b. a permanent magnetic layer formed on the seed layer, wherein the permanent magnetic layer comprises a material chosen from the group consisting essentially of Co₃Pt, SmCo₅, and alloys FePt, FePd, FeNdB, and MnAl.

15

20

12. The sensor of claim 4, wherein the seed layer further comprises a metallic layer bonded to the alloy layer comprising the alloy, wherein the permanent magnetic layer is in contact with the layer comprising the alloy.

25

13. The sensor of claim 12, wherein the metallic layer comprises a soft magnetic material.

14. The sensor of claim 13, wherein the soft magnetic material is chosen from the members of the group consisting essentially of Cr, Ta, CrZnNb and an Fe-Al-Si alloy.

30

15. A magnetic sensor, comprising:

- a. a giant-magnetoresistive sensing layer comprising a ferromagnetic free layer having a saturation magnetization; and
- b. a hard bias layer positioned to maintain the free layer in a single-domain state, and having a magnetic remnance times thickness at least two times the value of the saturation magnetization times thickness of the free layer.

16. A magnetic disk drive system, comprising:

- a. a surface of a magnetic media;
- b. a magnetic sensor of claim 1 positioned in proximity to the surface of the magnetic media; and
- c. a driving mechanism configured to cause relative motion between the surface and the sensor.

17. A method of making a magnetic sensor, the method comprising:

- a. forming a giant-magneto-resistive sensing layer having a top surface, a bottom surface and at least a side surface intersecting the top and bottom surfaces, at an angle substantially different from 180 degrees;
- b. depositing seed layer abutting the sensing layer at the side surface, the seed layer comprising an alloy between two elements chosen from the group consisting essentially of W, Mo, Cr, V, Nb, Ta, Ti, Hf and Zr, wherein the two elements have different crystal structures; and
- c. depositing, subsequent to step (b), a layer of permanent magnetic material on the seed layer.

18. A magnetic sensor, comprising:

- a. a giant-magnetoresistive sensing layer comprising a ferromagnetic free layer; and
- b. means for maintaining the free layer in a single-domain state.

19. A method for making a magnetic sensor, the method comprising:

- a. providing a giant-magnetoresistive sensing layer having a ferromagnetic free layer; and
- b. maintaining the free layer in a single-domain state.

5

20. The method of claim 19, wherein step (b) comprises providing a hard bias layer having a coercivity of at least 2,000 Oe.

10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
265
270
275
280
285
290
295
300
305
310
315
320
325
330
335
340
345
350
355
360
365
370
375
380
385
390
395
400
405
410
415
420
425
430
435
440
445
450
455
460
465
470
475
480
485
490
495
500
505
510
515
520
525
530
535
540
545
550
555
560
565
570
575
580
585
590
595
600
605
610
615
620
625
630
635
640
645
650
655
660
665
670
675
680
685
690
695
700
705
710
715
720
725
730
735
740
745
750
755
760
765
770
775
780
785
790
795
800
805
810
815
820
825
830
835
840
845
850
855
860
865
870
875
880
885
890
895
900
905
910
915
920
925
930
935
940
945
950
955
960
965
970
975
980
985
990
995